Final report:

Aluminium based Nanoeutectics: Synthesis and Microstructure

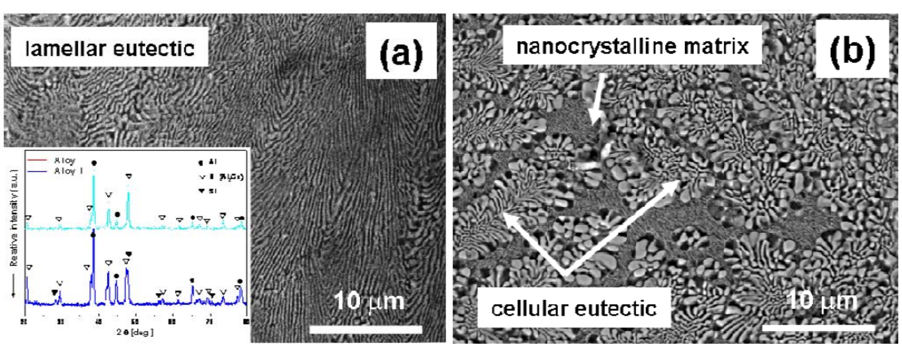
Abstract: The primary aim of the project was to explore the possibility of synthesising high strength multiphase eutectic alloys based on aluminium which also exhibits reasonable ductility. The approach used was to develop a multiscale microstructure including nanometer length scale eutectic colony using ternary alloys and evaluate their deformation behaviour. We have carried out work on two alloy systems, Al-Cu-Si and Al-Fe-Ni. Both exhibit ternary eutectic reaction. The microstructures were manipulated by imparting high cooling rates during solidification. In case of Al -Cu-Si system, we are successful in obtaining a dual length scale microstructure in the nanometric range. In a $Al_{81}Cu_{13}Si_6$ alloy, this has resulted in a material whose strength exceeds 1 GPa with 11% plastic strain. In the case of Al-Fe-Ni system, the ternary nanoeutectic (Al 3 at % Ni 0.3at% Fe) produced by very high rate of solidification yielded moderate strength (260MPa) with 12% ductility. However, even at 300^{o}C, the composite shows a yield strength of 170MPa.These results indicate that nanostructuring of the eutectic structure can yield a new class of materials with good high temperature strength.

The main results

Al-Cu-Si nanoeutectic

This part of the work has been carried out in collaboration with Yonsei University, Korea. The basic idea is to create a microstructure which contains two eutectics (binary and ternary) with two different nanometric length scales. We succeeded to synthesise such microstructure through rapid solidification processing utilising suction casting technique.

Fig.1 a) lamellar microstructure of Al-Cu binary eutectic alloy.b) multilength scale microstructure of a suction cast $Al_{81}Cu_{13}Si_6$ alloy. Inset of fig 1a show the x-ray powder patterns of the phases present



These alloys are tested under compressive loading. Fig. 2 a shows the deformation behaviour. We have also included the results from a binary Al-cu eutectic alloys processed under similar condition.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
30 JAN 2010	**FInal**	**02-02-2008 to 02-04-2009**

4. TITLE AND SUBTITLE
Aluminum based Nanoeutectics : Synthesis and Microstructure

5a. CONTRACT NUMBER
FA48690814002

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Kamanio Chattopadhyay

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Indian Institute of Science,Department of Material s Engineering,Bangalore 560 012,India,IN,560012

8. PERFORMING ORGANIZATION REPORT NUMBER
N/A

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
AOARD, UNIT 45002, APO, AP, 96337-5002

10. SPONSOR/MONITOR'S ACRONYM(S)
AOARD

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The primary aim of the project was to explore the possibility of synthesizing high strength multiphase eutectic alloys based on aluminium which also exhibits reasonable ductility. The approach used was to develop a multiscale microstructure including nanometer length scale eutectic colony using ternary alloys and evaluate their deformation behavior. We have carried out work on two alloy systems, Al-Cu-Si and Al-Fe-Ni. Both exhibit ternary eutectic reaction. The microstructures were manipulated by imparting high cooling rates during solidification. In case of Al -Cu-Si system, we are successful in obtaining a dual length scale microstructure in the nanometric range. In a Al81Cu13Si6 alloy, this has resulted in a material whose strength exceeds 1 GPa with 11% plastic strain. In the case of Al-Fe-Ni system, the ternary nanoeutectic (Al 3 at % Ni 0.3at% Fe) produced by very high rate of solidification yielded moderate strength (260MPa) with 12% ductility. However, even at 300oC, the composite shows a yield strength of 170MPa.These results indicate that nanostructuring of the eutectic structure can yield a new class of materials with good high temperature strength.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**3**	

This alloy does not show the multiscale microstructures. Both strength and ductility are much higher in our case (1.1 GPa and 12% plastic strain). Fig 2b&c shows the fracture surface clearing showing dimples in the aluminium matrix.

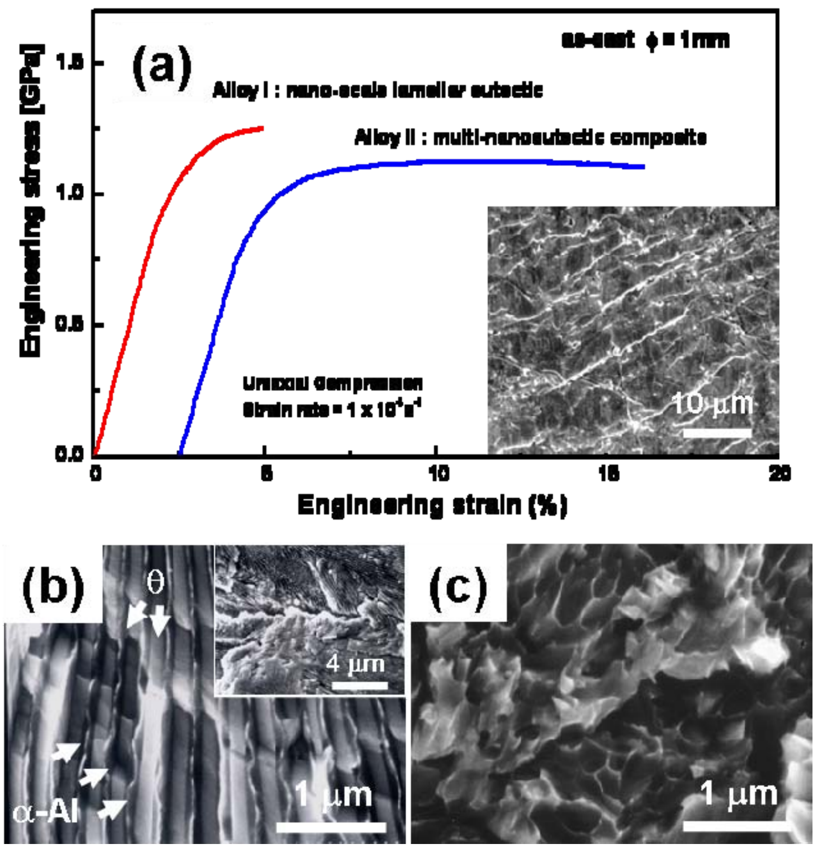


Fig. 2 a) comparative tensile strength of binary Al-Cu eutectic (alloy 1) and ternary eutectic (alloy 2) obtained by suction casting to yield nanostructure. b&c) Morphology of fracture surfaces

The Al-Fe-Ni system Like Al-Cu-Si system, this system also exhibits a ternary eutectic reaction at aluminium rich end. Fig 3 shows typical microstructure when a eutectic alloy of Al 3 at % Ni 0.3at% composition is suction cast. This microstructure is of nanometric scale. As shown in the inset, they contain two types of eutectics. In this case both the eutectics are binary eutectic s(Al-Al3Ni and Al-Al9FeNi). The increase in strength in this case is only moderate (tensile strength of 220 MPa at room temperature). However, attaining the nanometric eutectic microstructure leads to development of high ductility of the composite (~12%). Fig. 4 shows typical stress strain plot under tension for both as cast and suction cast materials. The microstructure is stable up to 350^{0}C (20hr). At 300^{o}C, the tensile strength is 160MPa, similar to the strength of the alloy in the as cast condition.

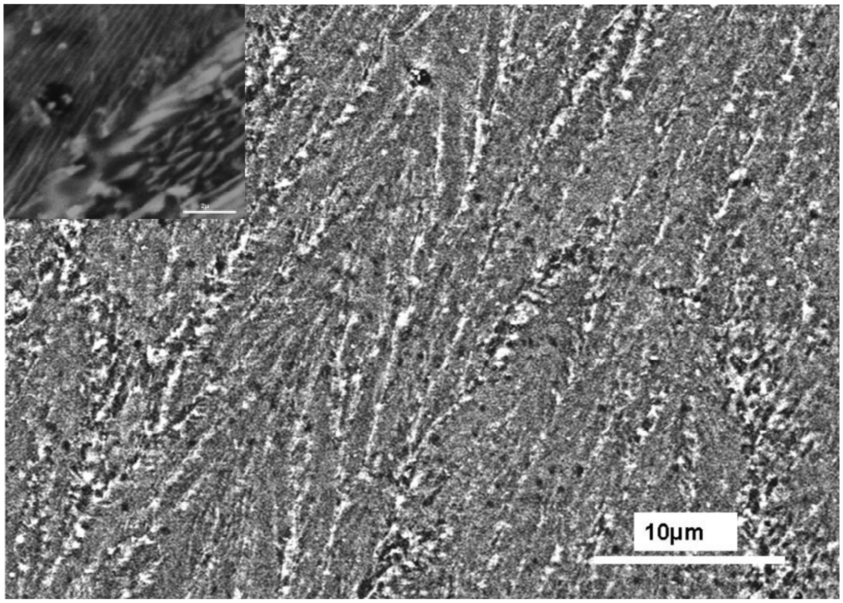


Fig.3 Microstructure of suction cast nanoeutectics containing two eutectics (30-40 nm and 70-80 nm average spacing)

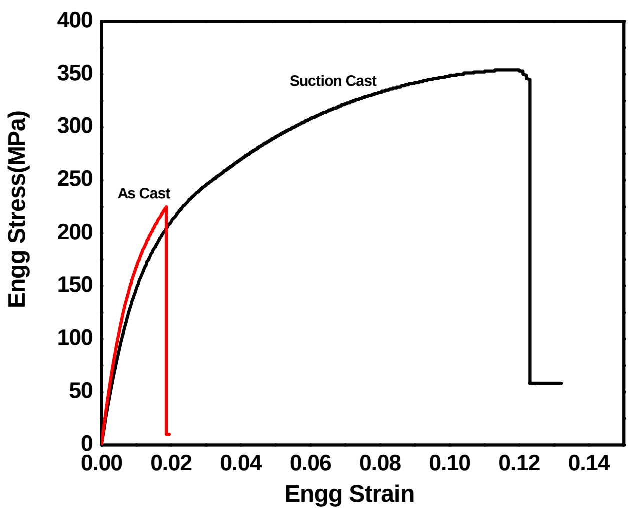


Fig.4. Stress –strain plot of the Al-Fe-NI nanoeutectic obtained by suction casting. The red curve is from the same materials processed under normal casting condition.

Conclusion

The present programme of research showed that it is possible to manipulate the eutectic length scales by rapid solidification. The resultant nanostructured materials with different length scale not only improves the strength but also ductility of the composites. Detailed TEM investigations and analysis of fracture surfaces (not shown here) indicate that such structure can accommodate local strains more effectively resulting in higher ductility even under tensile loading. Future work is being planned to understand the micro mechanism of such deformation processes.s

Publications

1. High Strength Al rich Al-Fe-Ni ultra-fine eutectic with high plasticity

   Chandrasekhar Tewari, Sanjay Kashyap and K.Chattopadhyay (to be submitted)

2. High strength bulk Al based bimodal ultrafine eutectic composites with enhanced plasticity

   J.M.Park , N.Matten,U.Kuhn,J.Eckert, K.B.Kim, W.T.Kim, K.Chattopadhyay and D.H.Kim

   J.Materials Research 24 (2009) pp2605-2609